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Harbour Porpoise (*Phocoena phocoena*) summer abundance and distribution in the German North and Baltic Seas

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Harbour porpoise (*Phocoena phocoena*) summer abundance and distribution in the German North and Baltic Seas

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ABSTRACT
From May to August 2002 and 2003 aerial surveys were conducted in parts of the German North and Baltic Seas. Distance sampling as well as the circle back method were used to calculate estimated strip width (ESW) and g(0) in different sighting conditions. Results were applied to the survey data to estimate density of harbour porpoises in the study area as animals per km². Abundance was calculated for four survey blocks in the German North Sea, and three survey blocks in the German Baltic Sea. Additionally, a 10x10 km grid of cells was applied to the original data to show the mean summer distribution in the study area. In the North Sea density varied slightly between years for different blocks. The highest density was found in the northern part of the German North Sea, close to the Danish border. The overall summer abundance of porpoise in the German North Sea was 36 672 animals (C.V. = 0.10). In the Baltic Sea, the density changed between years in the eastern block close to the Polish border with a density of 0.33 porpoises per km² in 2002 and 0.00 porpoises per km² in 2003. No overall abundance could be provided for the entire Baltic Sea study area due to the poor coverage of the western part in 2002.

1. Introduction

Harbour porpoise (*Phocoena phocoena*) is the only cetacean species found in both the German North and Baltic Seas on a regular basis (Reijnders 1992; Benke & Siebert 1994; Schulze 1996; Benke *et al.* 1998; Hammond *et al.* 2002). Until recently, only limited data existed on the distribution and density of harbour porpoise in the German North and Baltic Seas. Most of what was known was based on results of the SCANS (Small Cetacean Abundance in the North Sea and Adjacent Waters) survey undertaken in July 1994 (Hammond *et al.* 1995, Hammond *et al.* 2002). Unfortunately, SCANS did not include some areas of the German exclusive economic zone (EEZ), such as the region east of the island of Ruegen close to the Polish border in the Baltic and some parts off the East Frisian Islands between the Elbe estuary and the Dutch border in the North Sea.

Aerial surveys conducted in 2002 and 2003 in the German North and Baltic Seas increased our knowledge on the summer distribution of porpoises in this area considerably (Scheidat *et al.* 2003). However, an abundance estimate of porpoise in German waters was still missing. Abundance estimates are urgently needed in order to obtain a baseline for management decisions with respect to the proposed construction of windmill parks or the implementation of special areas of community interest (SCI). In this paper we present results on distribution as well as density and abundance estimates for harbour porpoise in German waters during summer months.

2. Methods

Study Area

The study area in the North Sea included the German EEZ as well as the 12nm zone in front of the coastline (Figure 1). For the purpose of our surveys the study area in the North Sea was divided into four different survey blocks (A to D, Table 1). In the Baltic Sea, the study area was extended outside the EEZ to include Danish waters. The southern coastline of the Danish isles were selected as a natural northern boundary of the study area (Figure 2). The Baltic was separated into three survey blocks (E to G). The size of the blocks are shown in Table 2. One block was usually surveyed within one day (between 3 to 9 hours of flight).

Survey Design and Data Acquisition

Surveys were following standard line-transect methodology for aerial surveys (Hiby & Hammond 1989; Buckland *et al.* 2001). From May 2002 to August 2003, flights were conducted along a predetermined parallel track design and the starting point was chosen randomly. The direction of tracks was either north-south or east-west in order to follow depth gradients. The aircraft used was a high-winged twin engine Partenavia, equipped with bubble windows, flying at an altitude of 182 m (600 ft) and with a speed of 167 to 186 km/hr (90 to 100 kts). Data collection was based on the "VOR" software designed by Lex Hiby and Phil Lovell and described in Hammond *et al.* (1995).

The position of the aircraft was recorded automatically every four seconds onto a laptop computer connected to a GPS. Additionally, any sigthing position of a marine mammal was stored. Sea state (according to the Beaufort scale), glare, cloud cover (parts of eight), turbidity (judged visually: 0 - clear water with several meters of visibility to 2 - very turbid water with no visibility beneath the surface) and sighting probability (judged subjectively as "good", "moderate" or "poor" by observers as probability to sight a porpoise by taking into account all environmental conditions) were entered at the beginning of each transect and whenever any of the environmental conditions changed during a transect. Sighting data were acquired by two observers located at each of the bubble windows of the aircraft. Data were entered into the computer by the navigator, located in the co-pilot's seat. Sighting data included species, group size, presence of calves, behaviour, swimming direction, cue, reaction to the survey plane, location of porpoise (at surface or under water) and clinometer angle measured from the aircraft abeam to the porpoise group.

Data Analysis

Using line-transect and distance sampling methodology as well as the Hiby and Lovell circle-back method, an effective strip width (esw)[1] including g(0)[2] under the different subjective sighting conditions "good" and "moderate" was calculated. Details on the method are provided in Hiby and Lovell (1998). Tracks flown in sighting condition "poor" were excluded.

After each flight a self-designed program "GSEMERGE" summarises all data collected during the surveys in a four-second-interval. For each of these four-second-intervals the exact distance flown was

[1] esw = the half-strip width of the area searched effectively on each side of the line transect (Buckland *et al.* 2001).

[2] g(0) = probability of detection on the transect line, usually assumed to be 1. In the case of marine mammals, that spend substantial periods underwater and thus avoid detection, this parameter must be estimated from other type of information (Buckland *et al.* 2001).

determined (around 200 m). Using the calculated effective half-strip width for the subjective sighting conditions (determined for each observer side seperately), the area (in km^2) covered during each four-second-interval was calculated. The number of animals seen was then divided by the area for each interval and the absolute density of porpoises (animal per km^2) was calculated. For the purpose of this paper, both data sets obtained in May to August 2002 and 2003 were analysed.
Further analyses included the calculation of a grid (cell size: 10 x 10 km). For each cell of the grid harbour porpoise density was calculated. Data were analysed and visualised using a GIS software (ArcGIS 8.2).

Surveys in 2002 and 2003 were considered as independent samples. Estimates of mean abundance were based on a comparison of these two values. Variables were log-transformed as they were not normally distributed. Because of zero values in block G in 2003 the log+1 transformation was used. For these transformed values the mean, the coefficient of variation (CV) and the overall 95% confidence interval (C.I.) were calculated. The back-transformed mean of a logarithmically transformed variable is called the geometric mean (GM). It is less affected by extreme values than the arithmetic mean and is useful as a measure of general tendency for skewed distributions. The coefficient of variation (CV) was calculated by dividing the standard deviation by the mean. Additionally, the coefficient of variation was corrected (CV*) for bias using the following formula: $CV^* = (1+1/4n) \times CV$ (Sokal & Rohlf 1995).
To calculate the overall C.I. the sum of all blocks covered in each of the two years was calculated. After back- transformation the corresponding 95% CI's were calculated. Because of the small sample size the 95% confidence interval was calculated using the t value of 12.71 (instead of the z value of 1.96 used for larger sample sizes).
The overall confidence interval was only calculated for the North Sea as block E in the Baltic Sea was not covered in 2002.

3. Results

Esw and g(0)

The effective half-strip width calculated, based on the distance of the sightings to the tracklines, was 0.128 km with a g(0) of 0.568 in good conditions. The effective strip width was reduced to 0.036 km with a g(0) of 0.164 in moderate conditions. Due to the still comparatively low number of circle flights 95% confidence limits on the g(0) estimate under "good" conditions remained wide and span almost over the entire range from 0 to 1. Additional circle flights will be conducted in the near future. The increased number of circle flights is likely to reduce 95% confidence limits and thus provide a better estimate of g(0).

North Sea

Between May and August 2002, 330 sightings of harbour porpoise pods were made. A total of 431 animals were counted, 13 (3%) of them were calves. Between May and August 2003, 692 harbour porpoise pods were sighted. A total of 853 animals was counted, 52 (6.1%) of them were calves.

Figure 1 shows the distribution of harbour porpoise in the North Sea study area combining sightings obtained in the summers of 2002 and 2003. Empty (white colour) cells indicated that no animals were detected in these cells in the course of our surveys. Sighting conditions in the southern part of block B (Offshore) were unfavourable both during 2002 and 2003. No sightings were obtained under ‘good’ or ‘moderate’ conditions. Density estimates of harbour porpoise varied considerably between survey blocks. Highest densities were found along the northern border to Denmark in block C and locally in block B. There appeared to be a gradient towards lower density from the north to the south of the study area.

Table 1 showed the mean density of harbour porpoises for each survey block (A to D) in 2002. Highest densities were observed in survey block C. The lowest densities were recorded in block D. The abundance between blocks varied from 2002 to 2003. However, mean abundance for the whole survey area was very similar between 2002 and 2003.

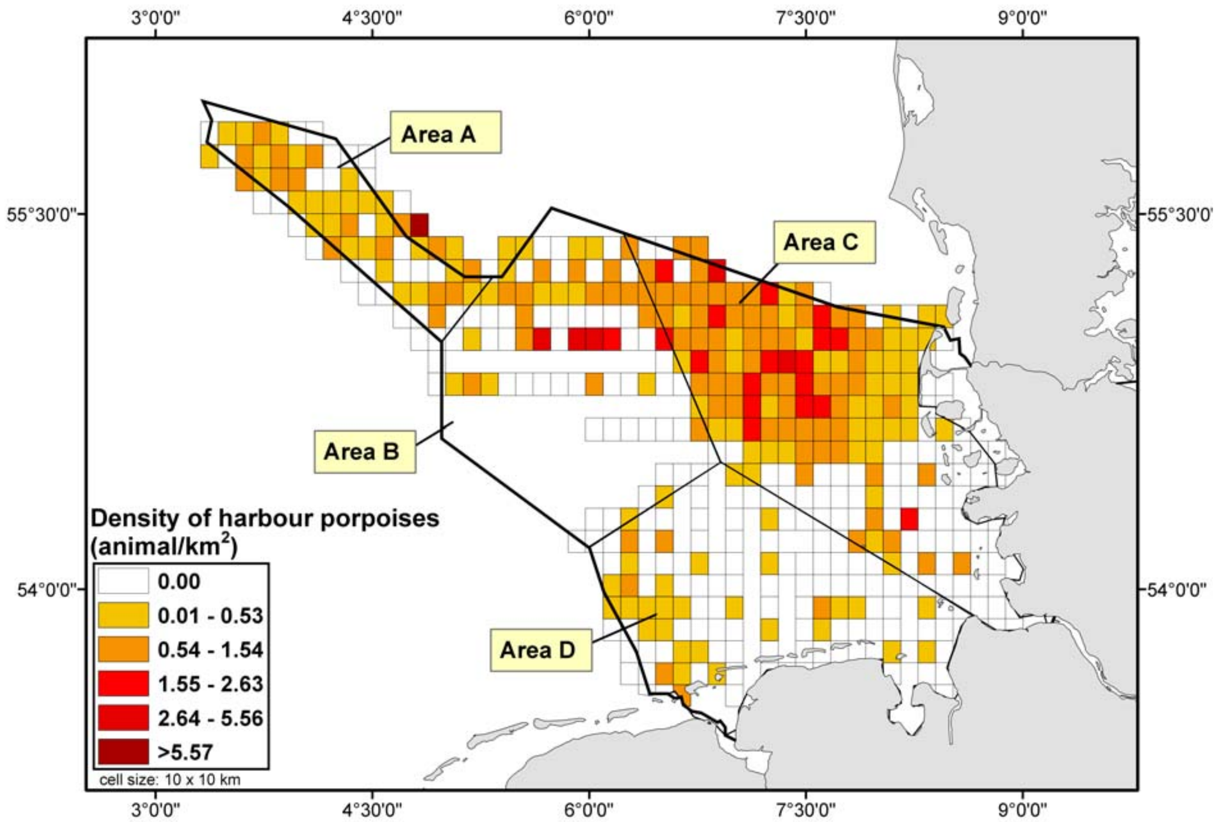

Figure 1: Map showing the distribution of harbour porpoises in the German North Sea for May to August 2002 and 2003. Density is shown as animals per km² per cell (10x10km). Only flights conducted in good or moderate conditions were included. Block A – Entenschnabel, block B – Offshore, block C – North Frisia, block D – East Frisia. Map projection: UTM.

Table 1: Density of porpoises in the German North Sea (from May to August). A= 'Entenschnabel', B= Offshore, C= North Frisia and D= East Frisia. The coefficient of variation (C.V.) was calculated for each block separately using the values of 2002 and 2003 as samples. The mean is the geometric mean (GM) based on log-transformed data. (# = number of porpoises)

Block	Size (km²)	Effort (km²) 2002	# porp.	Density (#/km²) 2002	Effort (km²) 2003	# porp.	Density (#/km²) 2003	Abundance per block 2002	Abundance per block 2003	Mean (GM) abundance 2002 and 2003	C.V.
A	3 903	3.9	4	1.03	110.33	90	0.82	4 003	3 184	**3 570**	0.18
B	11 650	56.36	33	0.59	58.06	42	0.72	6 821	8 427	**7 582**	0.17
C	13 668	231.31	353	1.53	379.35	703	1.85	20 859	25 329	**22 986**	0.15
D	11 824	179.69	41	0.23	97.88	18	0.18	2 698	2 174	**2 422**	0.17

Baltic Sea

Between May and August 2002, 51 sightings of harbour porpoise pods were obtained. A total of 79 animals were counted, one of them (1.3%) was a calf. Between May and August 2003, 32 harbour porpoise pods were sighted. A total of 41 animals were counted, three of them (7.3 %) were calves. Harbour porpoise distribution, combined for the years 2002 and 2003, was exhibited in Figure 2. The density of porpoises showed higher values in the Kiel and Flensburg Bights in the west and close to the border of Poland in the east which much less sightings in between. All sightings east of the island of Ruegen were conducted in 2002.

There was a change in abundance of harbour porpoise in the Baltic Sea between years. Table 2 demonstrates the mean number of animals in 2002 and 2003. The resulting coefficient of variation for block G is very large.

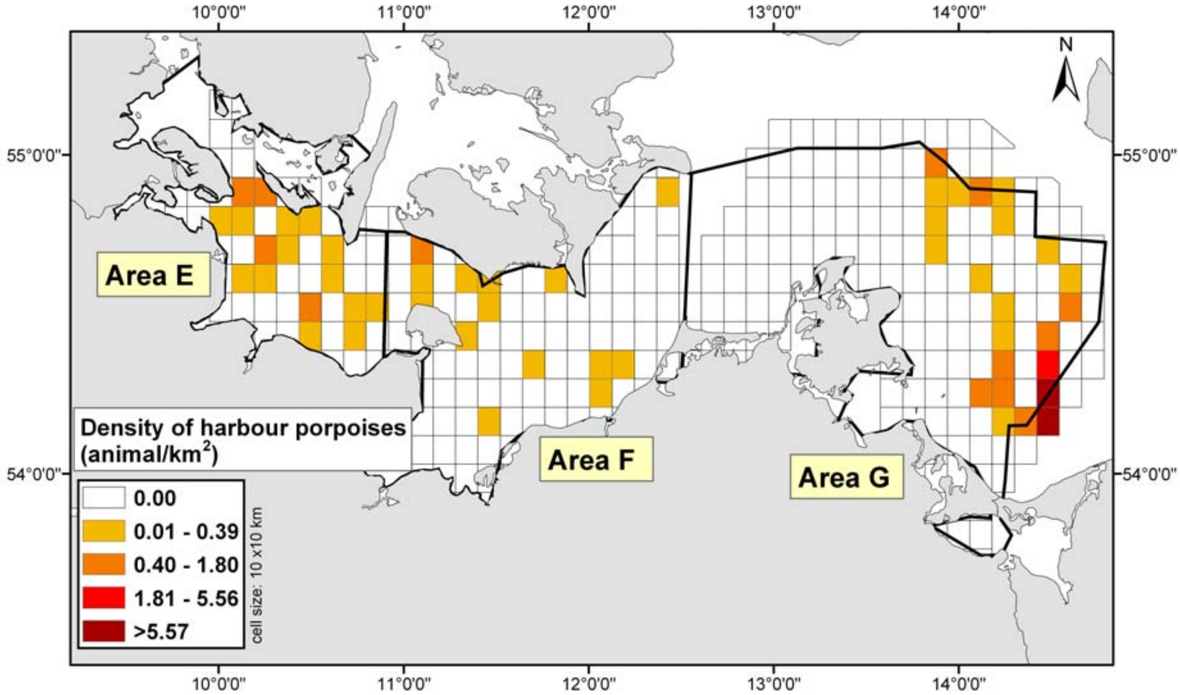

Figure 2: Map showing the distribution of harbour porpoises in the Baltic Sea study area for May to August 2002 and 2003. Density is shown as animals per km² per cell (10x10km). Only flights conducted under good or moderate conditions were considered. Block E – Kiel Bight, block F – Mecklenburg Bight, block G – Ruegen. Map projection: UTM.

Due to the limited coverage in block E in 2002 no mean abundance were obtained for the years 2002 and 2003 (Table 2). Therefore, overall mean abundance was calculated without considering this block. Density in block E was different between the two years (0.13 animals per km² in 2002 and 0.06 animals per km² in 2003). This resulted in a C.V. of 0.62. However, the density in block G was rather different between years with a mean density of 0.33 porpoises per km² in 2002 and no sightings obtained in 2003.

Table 2: Density of porpoises in the Baltic Sea study area (from May to August). The coefficient of variation (CV) was calculated for each area using the values of 2002 and 2003 as samples. The mean is the geometric mean (GM) based on log-transformed data.

Area	Size (km²)	Effort (km²) 2002	# porp.	Density (#/km²) 2002	Effort (km²) 2003	# porp.	Density (#/km²) 2003	Abundance per block 2002	Abundance per block 2003	Mean (GM) abundance 2002 and 2003	CV
E	4 696	-	-	-	110.46	29	0.26	-	1 233	-	-
F	7 248	151.70	20	0.13	214.44	12	0.06	956	406	**623**	0.62
G	10 990	179.68	59	0.33	143.58	0	0.00	3 609	0	**59**	43.19

Overall density

We were unable to calculate overall density for the Baltic Sea because of the lack of coverage of block E in 2002. For the North Sea, density, CV and confidence interval were calculated using the total from the four survey blocks. For the North Sea, overall density was 36 672 animals with a 95% confidence interval of 16 154 to 83 247 animals (Table 3).

Table 3: Calculation of overall harbour porpoise abundance in the German North Sea during the months May to August. Mean presented is based on the log-transformed data.

	2002	2003	Mean (geometric)	CV	Lower 95% C.I.	Upper 95% C.I.
German North Sea	34 381	39 115	**36 672**	0.10	**16 154**	**83 247**

4. Discussion

North Sea

Highest densities of harbour porpoise in the North Sea in May to August were observed in the northern part of the German EEZ, close to the Danish border. In the remainder of the study area, harbour porpoise were more evenly distributed and no aggregations were found. However, coverage in good or moderate conditions was low in the south-western offshore area, which leads to limited data on porpoise distribution in this block. The high density of porpoises in the northern part of the German North Sea might be due to the fact that the animals aggregated to reproduce. Harbour porpoises have a gestation time of 10 to 11 months and therefore mating and calving takes place at about the same time each year. In Danish and German waters reproduction takes place from mid July to August (Kinze 1994; Benke *et al.* 1998; Bandomir *et al.* 1999). The German Bight has a high pregnancy rate of 0.8 (Bandomir-Krischak 1993; Bandomir *et al.* 1999). This suggests that most female porpoises are pregnant and lactating at the same time. During this time, porpoises have a high energy demand and are especially dependent on high quantity and/or quality of food items (Read & Hohn 1995; Read *et al.* 1997). The large density of porpoises over an extended area (about 60 km diameter) could mirror the social behaviour during calving and mating as well as a rich, possibly only temporary, food source. Porpoises feed on fish especially those with a high energy content, such as the herring (*Clupea harengus*) and sprat (*Sprattus sprattus*) (Rae 1973; Recchia & Read 1989; Schulze 1996; Benke et al. 1998; Gannon *et al.* 1998). These fish aggregate in large and dense schools which are often linked to frontal systems. The aggregation along frontal systems was also known from seabirds (Camphuizen 2001; Camphuizen & Webb 1999; Skov 2000; Skov & Prins 2001)

The highest density of porpoises was found in block C and the lowest in block D both in 2002 and in 2003. The offshore blocks A and B were similar in terms of porpoise density within years as well as between years. Density and the resulting abundance estimates varied between survey blocks and years. However, mean abundance for the whole survey area was very similar between the two years. Harbour porpoise are known to be mobile and may travel several ten miles per day. Such short-term movements of porpoises would lead to changes in density estimates for each region. Therefore, such difference in density between neighbouring blocks can be anticipated. These differences are likely to be levelling off if a larger area, such as the German EEZ is considered as could be seen from the rather small difference between surveys conducted in 2002 and 2003.

Baltic Sea

Most animals in the Baltic Sea were detected in Kiel Bight (block E) and on the Oderbank in the eastern part of block G close to the Polish border. In both years, sighting rates were lowest in survey block F (Mecklenburg Bight). Mean summer density in block E was 0.26 porpoises per km² in 2003. This is higher than the density obtained during SCANS in July 1994 in area X (an area very similar in size and location to the Kiel Bight area) with a density of 0.101 porpoises per km² (Hammond et al. 2002).

In contrast to the North Sea the density in certain blocks, such as block G changed dramatically from one year to the other. Comparatively high densities of harbour porpoise were observed in 2002 while no sightings were obtained in 2003. Porpoises occurring east of the Darss – Limhamn ridge are considered to belong to a population different from the western Baltic (Tiedemann *et al.* 1996; Börjesson & Berggren 1997; Huggenberger *et al.* 2002). The population of porpoises in the central Baltic was estimated at 599 animals (CV=0.57) in 1995 (Berggren 1995). It seems as if animals frequent this area only occasionally. Porpoise distribution may be linked to the abundance of prey (Katona & Whitehead 1988; Evans 1990; Reijnders 1992), such as herring, aggregating in the area. Aggregations of up to 100 porpoises have been observed in the North Sea (Rae 1965; Evans 1990).

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